Smart Grid – An Intelligent Power System: Review and Future Challenges

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Abstract

Electricity networks are extensive and well established. They form a key part of the infrastructure that supports industrialised society. The main focus of Intelligent Energy System is how energy can be effectively and efficiently utilized. New electrical transmission systems, smart grid and modern electrical systems, smart houses and homes, and other energy efficiency improvement are included. Smart grid has replaced traditional electrical power grid with its various technologies. In today's world smart grid has emerged as a solution of increasing energy demand since they deliver energy at low cost and high quality as possible. The smart grid successfully uses renewable energy resources and smart pricing technique in order to achieve energy efficiency. Information communication technology helps the grid in collection of data from various consumers. Basically advanced metering infrastructure comprises of collection, storing and using energy usage data are assumed to be the main tool of smart grid. This paper deals with the pros and of smart grid technology.

***Key Words*: Smart grid, bidirectional energy flow, demand side management, Sustainability, Accountability, Advanced Metering, RF Emissions, Cyber attacks**

1. INTRODUCTION

Electricity networks are moving from a period of stability to a time of potentially major transition, driven by a need for old equipment to be replaced. These are being substituted by cleaner and renewable sources of electricity generation. The novel transmission and distribution systems of the future will challenge today's system designs. They will cope with variable voltages and frequencies, and will offer more flexible, sustainable options.

Intelligent power networks will need innovation in several key areas of information technology. Active control of flexible, large-scale electrical power systems is required. Protection and control systems will have to react to faults and unusual transient behaviour and ensure recovery after such events. Real-time network simulation and performance analysis will be needed to provide decision support for system operators, and the inputs to energy and distribution management systems. Advanced sensors and measurement will be used to achieve higher degrees of network automation and better system control, while pervasive communications will allow networks to be reconfigured by intelligent systems.

2. SMART GRID : AN OVERVIEW

A **smart grid** is an electrical grid which includes a variety of operation and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources. [1] *The European Union Commission Task Force for Smart Grids* also provides smart grid definition as:

A Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies in order to:

1. Better facilitate the connection and operation of generators of all sizes and technologies.
2. Allow consumers to play a part in optimising the operation of the system.
3. Provide consumers with greater information and options for how they use their supply.
4. Significantly reduce the environmental impact of the whole electricity supply system.
5. Maintain or even improve the existing high levels of system reliability, quality and security of supply.
6. Maintain and improve the existing services efficiently

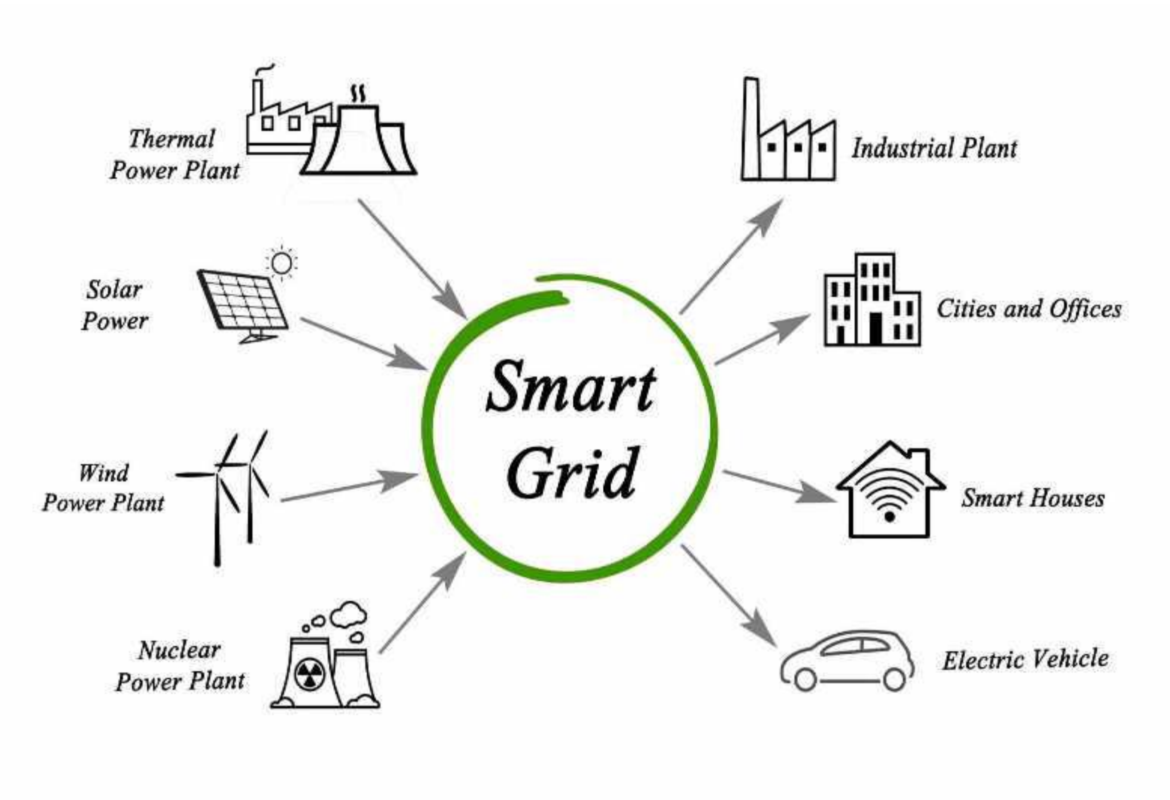

Fig - 1: Latest Trends in Smart Grid Technology

3. BLOCK DIAGRAM OF SMART GRID

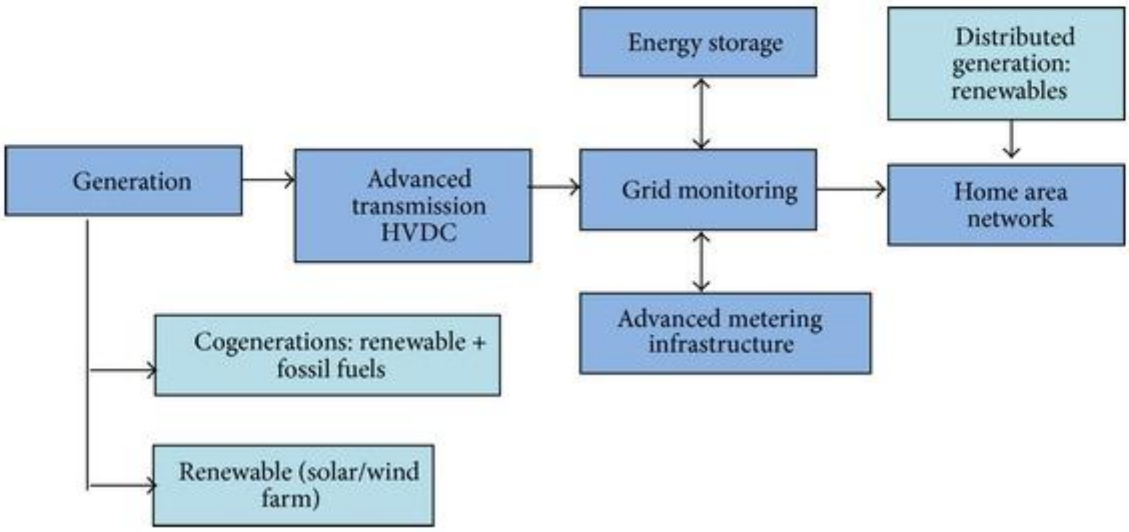

Fig - 2: Block Diagram of Smart Grid

4. FEATURES OF SMART GRID

4.1 Reliability

The smart grid makes use of technologies such as state estimation [2], that improve fault detection and allow self-healing of the network without the intervention of technicians. This will ensure more reliable supply of electricity, and reduced vulnerability to natural disasters or attack.

Although multiple routes are touted as a feature of the smart grid, the old grid also featured multiple routes. Initial power lines in the grid were built using a radial model, later connectivity was guaranteed via multiple routes, referred to as a network structure. However, this created a new problem: if the current flow or related effects across the network exceed the limits of any particular network element, it could fail, and the current would be shunted to other network elements, which eventually may fail also, causing a domino effect.

4.2 Flexibility

Next-generation transmission and distribution infrastructure will be better able to handle possible **bidirectional energy flows**, allowing for distributed generation such as from photovoltaic panels on building roofs, but also charging to/from the batteries of electric cars, wind turbines, pumped hydroelectric power, the use of fuel cells, and other sources.

Classic grids were designed for one-way flow of electricity, but if a local sub-network generates more power than it is consuming, the reverse flow can raise safety and reliability issues. [3] A smart grid aims to manage these situations. [4]

4.3 Efficiency

Numerous contributions to overall improvement of the efficiency of energy infrastructure are anticipated from the deployment of smart grid technology, in particular including **demand-side management**, for example turning off air conditioners during short-term spikes in electricity price, reducing the voltage when possible on distribution lines through Voltage/VAR Optimization (VVO), eliminating truck-rolls for meter reading, and reducing truck-rolls by improved outage management using data from Advanced Metering Infrastructure systems. The overall effect is less redundancy in transmission and distribution lines, and greater utilization of generators, leading to lower power prices.

4.4 Sustainability

The improved flexibility of the smart grid permits greater penetration of highly variable renewable energy sources such as solar power and wind power, even without the addition of energy storage. Current network infrastructure is not built to allow for many distributed feed-in points, and typically even if some feed-in is allowed at the local (distribution) level, the transmission-level infrastructure cannot accommodate it. Rapid fluctuations in distributed generation, such as due to cloudy or gusty weather, present significant challenges to power engineers who need to ensure stable power levels through varying the output of the more controllable generators such as gas turbines and hydroelectric generators. Smart grid technology is a necessary condition for very large amounts of renewable electricity on the grid for this reason.

5. CHALLENGES AND CONCERNS

Most opposition and concerns have centred on smart meters and the items (such as remote control, remote disconnect and variable rate pricing) enabled by them.

The key areas of concern are:

- "fair" availability of electricity
- complex rate systems (e.g. variable rates) remove clarity and accountability, allowing the supplier to take advantage of the customer
- remotely controllable "kill switch" incorporated into most smart meters
- giving the government mechanisms to control the use of all power using activities
- RF emissions from smart meters

5.1 Security

A smart grid has a large number of access points, like smart meters, defending all of its weak points can prove difficult.[5] While modernization of electrical grids into smart grids allows for optimization of everyday processes, a smart grid, being online, can be vulnerable to cyber attacks. [5,6] Transformers which increase the voltage of electricity created at power plants for long-distance travel, transmission lines themselves, and distribution lines which deliver the electricity to its consumers are particularly susceptible. Hackers have the potential to disrupt these automated control systems, severing the channels which allow generated electricity to be utilized. These systems rely on sensors which gather information from the field and then deliver it to control centres, where algorithms automate analysis and decision-making processes. These decisions are sent back to the field, where existing equipment execute them.[7] Additionally, intruders can again access via renewable energy generation systems and smart meters connected to the grid, taking advantage of more specialized weaknesses or ones whose security has not been prioritized. One of the key capabilities of this connectivity is the ability to remotely switch off power supplies, enabling utilities to quickly and easily cease or modify supplies to customers who default on payment. This is undoubtedly a massive boon for energy providers, but also raises some significant security issues. [8]

5.2 Power Theft / Power Loss

Various "smart grid" systems have dual functions. This includes Advanced Metering Infrastructure systems which, when used with various software can be used to detect power theft and by process of elimination, detect where equipment failures have taken place. These are in addition to their primary functions of eliminating the need for human meter reading and measuring the time-of-use of electricity.

The worldwide power loss including theft is estimated at approximately two-hundred billion dollars annually. [9] Electricity theft also represents a major challenge when providing reliable electrical service in developing countries

6. CONCLUSION

Ensuring a reliable, efficient, and affordable energy is a great challenge. Generating electricity from renewable energy sources can provide direct and indirect economic benefits in excess of costs as well as environmental benefits through the reduction of CO_2 emission. Policy makers should promote renewable resources (i.e., solar, wind, biomass, hydropower, and geothermal) for sustainable and carbon-free energy. It is predicted that about 57% of total energy demand could be generated from renewable sources by 2050. The renewable energy source power generation integrated into the smart grid system can be one of the best options for future energy security. The smart grid system addresses the degradation of energy source and modern information technology for communication and improves the efficiency of power distribution. A smart grid can transform the 20th century power grid as a more intelligent, flexible, reliable, self-balancing, and interactive network that enables economic growth, environmental oversight, operational efficiency, energy security, and increased consumer control. Moreover, the smart grid would create new markets as private industries develop energy-efficient and intelligent appliances, new communication capabilities, and smart meters. Smart grid can replace traditional forms of energy with renewable sources of generation. Renewable energy is always required by environmentalists in the hopes of developing a cleaner and more efficient power generation. A smart grid is environmentally beneficial because it utilizes the distribution of renewable sources. Smart grid offers a genuine path toward significant environmental improvement.

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